

**SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT**

**METHOD 4.1**

**DETERMINATION OF MOISTURE CONTENT IN STACK GASES**

**TECHNICAL SUPPORT SERVICES  
APPLIED SCIENCE AND TECHNOLOGY  
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## **METHOD 4.1**

### **DETERMINATION OF MOISTURE CONTENT IN STACK GASES**

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## **METHOD 4.1**

### **DETERMINATION OF MOISTURE CONTENT IN STACK GASES**

#### **Section 1 of 4**

#### **1. Overview**

##### **1.1 Principle**

A gas sample is extracted from the source. Moisture is removed from the sample stream and determined either volumetrically or gravimetrically.

##### **1.2 Applicability**

This method accurately determines moisture content needed to calculate emission data. Alternate means may be used to approximate percent moisture in setting isokinetic sampling rates prior to a pollutant emission measurement run. These include drying tubes, wet bulb-dry bulb techniques, condensation techniques, stoichiometric calculations, and previous source testing data.

Method 4.1 is conducted simultaneously with a pollutant emission measurement run. Calculation of percent isokinetic emission rate for the run must be based on the results of this method rather than an approximation method.

This method will likely yield inaccurate results when applied to saturated gas streams or gas streams that contain large quantities of water droplets.

Alternatively, with the approval of the Executive Officer, any system may be used that cools the sample gas stream and allows measurement of both the water that has been condensed and the moisture leaving the train, each to within 1 ml or 1 g.

Acceptable means involve measuring the condensed water, either gravimetrically or volumetrically, and measuring moisture leaving the train by (1) monitoring the temperature and pressure at the exit of the condenser and using Dalton's Law of Partial Pressures, or (2) passing the sample gas stream through a tared silica gel (or equivalent desiccant) trap, with exit gases kept below 15°C (60°F), and determining the weight gain.

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#### **Section 2 of 4**

## **2. Field Procedures**

### **2.1 Sampling Apparatus**

A schematic of the sampling train is shown in Figure 4.1-1. All components should be maintained and calibrated according to the procedure outlined in Method 5.1.

#### **2.1.1 Sampling Train**

##### **a. Probe**

The probe is constructed of stainless steel or glass tubing. When stack conditions permit, other metals or plastic tubing may be used, subject to the approval of Executive Officer.

b. Impinger Train

The train consists of four impingers connected in series with ground leak-free fittings or any similar leak-free non-contaminating fittings. The first and second impingers must be of Greenburg-Smith design with the standard tip. The third and fourth impingers must be of Greenburg-Smith design modified by cutting the insert so the tube end is 14 mm (0.5 in.) above the bottom of the flask. Materials other than glass, or flexible vacuum lines to connect the probe and impingers, are acceptable modifications. If desired, use a backup filter between the last impinger and the pump to prevent any accidental suction of silica gel into the pump.

c. Cooling System

This system is an ice bath container and dry ice pellets in water or crushed ice.

d. Metering System

This system includes a vacuum gauge, leak-free pump, thermometer capable of measuring temperature to within 3°C (5.4°F), dry gas meter capable of measuring volume to within 2 percent, and related equipment as shown in Figure 4.1-1. Other metering systems capable of maintaining a constant sampling rate and determining sample gas volume may be used, subject to the approval of the Executive Officer.

2.1.2 Barometer

A mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 2.5 mm (0.1 in.) Hg



is used. The barometric readings may be obtained from a nearby National Weather Service station. Request the station value (which is the absolute barometric pressure) and adjust for elevation difference between the NWS station and the sampling point at the rate of minus 2.5 mm (0.1 in.) Hg per 30 m (100 ft) elevation increase, or plus the same adjustment for elevation decrease.

#### 2.1.3 Graduated Cylinder and/or Balance

These are used to measure condensed water and moisture caught in the silica gel to within 1 ml or 0.5 g. Graduated cylinders should have subdivisions no greater than 2 ml and tolerance limits of  $\pm 1$  percent. Most laboratory balances are capable of weighing to the nearest 0.5 g or less. Such balances are suitable here.

#### 2.2 Procedure

This procedure is written for an impinger train incorporating volumetric analysis to measure the

condensed moisture, and for silica gel and gravimetric analysis to measure the moisture leaving the dry impinger.

The sampling point in the stack should be either at the center of the cross section or at a point no closer to the walls than 1.00 m (3.3 ft), unless the stack vents more than one source or dilution air is introduced just before the sampling location. In these cases, use a minimum of eight traverse points for circular stacks, a minimum of nine points for rectangular stacks having equivalent diameters less than 61 cm (24 in.), and a minimum of twelve traverse points in all other cases.

Locate the traverse points (if required) according to Method 1.1. The use of fewer points is subject to the approval of the Executive Officer. Select a probe and probe length suitable for sampling all traverse points. For large stacks, consider sampling from opposite sides of the stack (four sampling ports), to permit shorter probe lengths.

Mark the probe with heat-resistant tape or other method to indicate the probe distance into the stack or duct for each sampling point.

Determine a total sampling time to collect a minimum total gas volume of 0.60 scm (21 scf) at a rate no greater than 0.021 m<sup>3</sup>/min (0.75 ft<sup>3</sup>/min). When both moisture content and pollutant emission rate are to be measured, the moisture determination must be simultaneous with, and for the same total length of time as, the pollutant emission rate run unless moisture varies less than 2 percent over time.

Set up the sampling equipment as shown in Figure 4.1-1 (see Section 3 for train assembly). Place dry ice pellets in the water of the ice bath container. Perform a leak check before and after each test. Plug the probe and draw a 380 mm (15 in.) Hg vacuum; a lesser vacuum may be used if it is not exceeded during the test. A leakage rate in excess of either 4 percent of the average sampling rate or 0.0007 m<sup>3</sup>/min (0.02 ft<sup>3</sup>/min) is unacceptable.

During the sample run, maintain a sampling rate within 10 percent of constant rate unless the

stack flow rate changes by more than 20 percent, in which case the sample rate should be changed in proportion to the stack flow rate change. For each run record the data required on the example data sheet shown in Figure 4.1-2. Be sure to record the dry gas meter reading at the beginning and end of each sampling time increment, and whenever sampling is halted. Take other appropriate readings at each sample point at least once during each time increment.

To begin sampling, position the probe tip at the first traverse point. Immediately start the pump and adjust flow to the desired rate. Traverse the cross section (if required), sampling at each traverse point for an equal length of time. Add more dry ice pellets, if necessary, to maintain a temperature below 15°C (60°F) at the silica gel outlet.

After collecting the sample, conduct a leak check (mandatory) as described in Section 2.2.5.

Record the leak rate. If the leakage rate exceeds the allowable rate, the tester must either reject the test results or correct the sample volume, as described in Chapter X.

Conduct a gas volume meter check as described in

Method 5.1, Section 2.4 (mandatory). Measure the amount of condensed moisture as described in Section 3, Laboratory Procedures. Calculate the percentage moisture as described in Section 4, Engineering Calculations.

### 2.3 Calibration

Refer to Chapter III.

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#### **Section 3 of 4**

### **3. Laboratory Procedures**

#### **3.1 Apparatus**

##### **3.1.1 Sampling Train**

See Section 2.1.1.

##### **3.1.2 Graduated Cylinder and/or Balance**

See Section 2.1.3.

#### **3.2 Reagents**

##### **a. Silica gel**

Indicating-type, 6 to 16 mesh. Fresh or dried at 175°C for 2 hours.

b. Water

Deionized, distilled water to conform to ASTM specification D-1193-Type 3.

At the option of the chemist, the  $\text{KMnO}_4$  test for oxidizable organic matter may be eliminated when high concentrations of organic matter are not expected to be present. Reference to water throughout this method implies deionized, distilled water.

c. Stopcock Grease

d. Crushed Ice or Dry Ice Pellets

3.3 Pretest Preparation

No special pretest preparation is required.

3.4 Preparation of Sample Collection Train

Assemble the impingers as shown in Figure 4.1-1. Load the first two impingers with exactly 100 ml of water each. Leave the third impinger empty. Place about 200 g of silica gel in the fourth impinger and record its weight to the nearest

0.5 g. For volumetric analysis, the impingers may be connected at this point and the train sealed at both ends. For gravimetric analysis, weigh each impinger plus its contents to the nearest 0.5 g and record the weights. Connect the impingers and seal the train.

### 3.5 Leak Check

If preferred, perform leak check in the laboratory following the procedure outlined in Section 2.2.

### 3.6 Sample Recovery

Inspect the train for general condition. Note if the silica gel is completely expended and if the train or its components are sealed. Shake any condensed moisture from the probe and impinger connectors into the impingers.

### 3.7 Analysis

For volumetric analysis, carefully pour the impinger catches into a suitably sized graduated cylinder; measure and record the volume to the nearest ml. Weigh the last impinger plus



contents (silica gel) to the nearest gram and record. For gravimetric determination, weigh each impinger plus its contents to the nearest 0.5 g and record the weights.

### 3.8 Calculations

Subtract 200 ml initial volume from the volumetric measurement to obtain impinger gain in ml. Subtract impinger tare weights from the received weights to obtain impinger gain in grams. Subtract the silica gel tare weights from received weight to obtain silica gel gain in grams. Report the total impinger gain and the silica gel gain to the nearest g or ml. Also report if the silica gel was expended.

### 3.9 Calibrations

Check balance calibration against NBS traceable weights. Balance must be accurate and repeatable to 0.5 g. Use graduated cylinders with subdivisions no greater than 2 ml and tolerance limits of 1 percent for volumetric analysis.

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#### Section 4 of 4

#### 4. Engineering Calculations

Perform the following calculations, retaining at least one decimal figure beyond that of the acquired data. Round off figures after final calculation.

##### 4.1 Nomenclature:

$B_w$  = Water percent

$P_{bar}$  = Barometric pressure, in Hg

$P_{ma}$  = Absolute pressure at the gas meter, in. Hg

$\Delta P$  = Orifice pressure, in.  $H_2O$  (if used)

$V_{mstd}$  = Dry gas volume metered, corrected to standard conditions, dscf

$V_m$  = Dry gas volume metered, dcf

$y$  = Meter correction factor ( no units)

$T_m$  = Absolute temperature at meter, °R

$V_{wstd}$  = Volume of total water caught, corrected to standard conditions, scf

$V_1 = (V_C + V_S)$  = Volume of total water in the train, ml

$V_C$  = Volume of water condensed, ml

$V_S$  = Volume of water absorbed by silica gel, ml

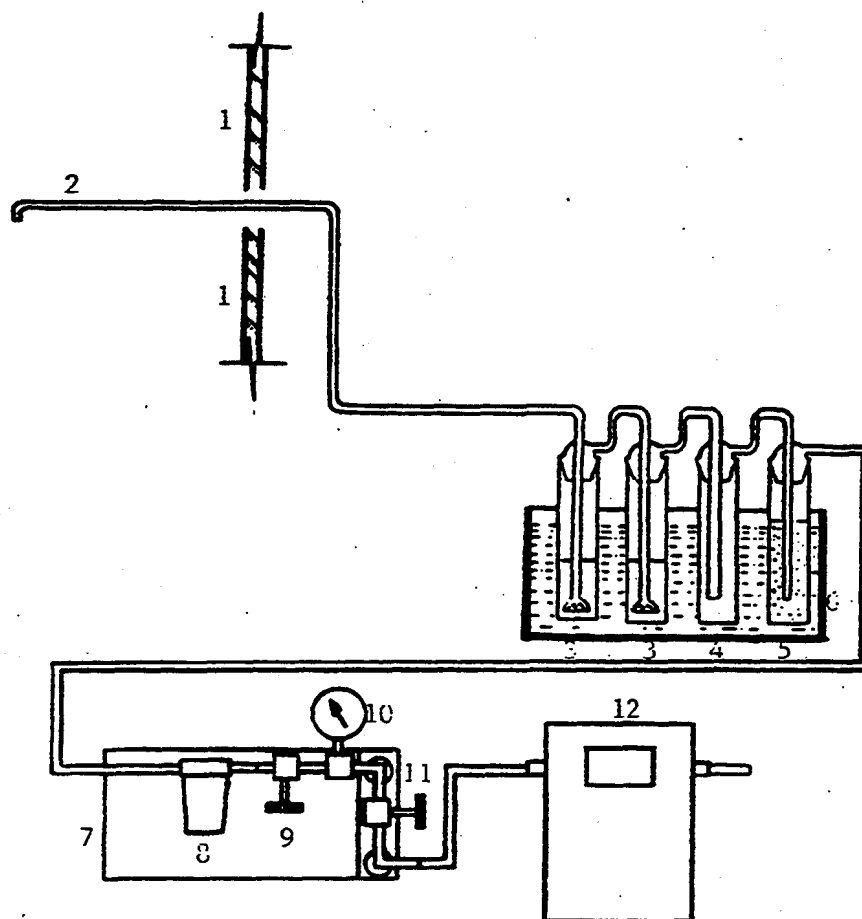
**Note:** If the post test leak rate (Section 2.2) exceeds the allowable rate, correct the value of  $V_m$  as described in Chapter X.

#### 4.2 Calculations

Perform the calculation shown on the Reporting Sheet (Figure 4.1-3).

**Table 4.1-1****Temperature-Moisture Relation**

Temp. °F	% H <sub>2</sub> O	Temp. °F	% H <sub>2</sub> O	Temp. °F	% H <sub>2</sub> O
50	1.2	130	15.1	180	51.1
60	1.7	140	19.7	185	57.0
70	2.5	150	25.3	190	63.6
80	3.5	155	28.7	195	70.8
90	4.8	160	32.3	200	78.6
100	6.5	165	36.4	205	87.0
110	8.7	170	40.8	210	96.2
120	11.5	175	45.7	212	100.0



- |   |                             |
|---|-----------------------------|
| 1. Stack Wall                               | 8. Filter for Pump          |
| 2. Probe                                    | 9. Metering Valve           |
| 3. Impinger with 100 ml of H <sub>2</sub> O | 10. Vacuum Gauge            |
| 4. Empty Bubbler                            | 11. By-pass Valve           |
| 5. Bubbler with Silica Gel                  | 12. Temperature Compensated |
| 6. Ice Bath                                 | Dry Gas Meter               |
| 7. Sealed Pump (Leak Free)                  |                             |

Figure 4.1-1  
Impingement Train For Moisture

Test No. \_\_\_\_\_ Date \_\_\_\_\_  
Sampling Location \_\_\_\_\_

### Pre-Test Velocity Leak Check

### Post-Test Velocity Leak Check

[illegible]

Static Pressure in Stack \_\_\_\_\_ "HgA (+/- \_\_\_\_\_ "H<sub>2</sub>O) (Average)  
Barometric Pressure..... \_\_\_\_\_ "HgA Pitot Factor.....  
Recorded By \_\_\_\_\_

Inclined Manometer \_\_\_\_\_ (Cal: N/A )  
Magnehelic No. \_\_\_\_\_ (Cal: \_\_\_\_\_ )  
Pitot Tube No. \_\_\_\_\_ (Cal: \_\_\_\_\_ )  
Potentiometer No. \_\_\_\_\_ (Cal: \_\_\_\_\_ )  
Thermocouple No. \_\_\_\_\_ (Cal: \_\_\_\_\_ )

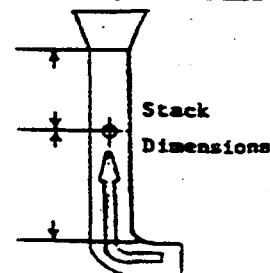
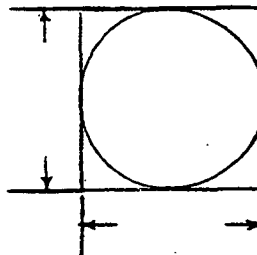


Figure 4.1-2  
Gas Velocity Data Sheet

# **MOISTURE CONTENT CALCULATION SHEET**

Time	Gas Vol. Metered ( $V_m$ ) $\text{ft}^3$	Meter Temp. ( $T_m$ ) $^{\circ}\text{F}$	Orifice Pressure ( $\Delta P$ ), in. $\text{H}_2\text{O}$

\_\_\_\_\_ **SAMPLING LOCATION**

Ambient conditions \_\_\_\_\_  $^{\circ}\text{F}$  \_\_\_\_\_ in. Hg  
 Assume 1 g  $\text{H}_2\text{O}$  = 1 ml  $\text{H}_2\text{O}$

**A. Gas Volume Metered ( $V_{mstd}$ )**

$$V_{mstd} = Y \cdot \frac{520^{\circ}\text{R}}{29.92 \text{ in. Hg}} \cdot \frac{V_m P_{ma}}{T_m} = (17.38) ( ) ( ) = \text{_____ dscf}$$

where:

$$P_{ma} = P_{bar} + (\Delta P / 13.6) = ( ) + \left( \frac{\text{_____}}{13.6} \right) = \text{_____ in. Hg}$$

**B. Volume of Water Condensed ( $V_{wstd}$ )**

$$V_{wstd} = (0.0464 \text{ ft}^3/\text{ml}) (V_1) = (0.0464) ( ) = \text{scf}$$

**C. Moisture in Stack Gas ( $B_w$ )**

$$B_w = \frac{V_w}{V_{mstd} + V_{wstd}} \times 100 = \frac{( )}{( )} \times 100 = \text{_____ \%}$$

**Figure 4.1-3**

**Reporting and Calculation Sheet for Moisture Content**

- D. If calculated moisture content is greater than at saturation temperature (e.g.  $212^{\circ}\text{F}$  or below) use the Table 4.1-1 for moisture content.

Figure 4.1-3 (Cont.)

Reporting and Calculation Sheet for Moisture Content